Cranberry Quality: Selection Procedures for Breeding Programs[1]

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Abstract. **Samples of 45 cranberry clones (*Vaccinium macrocarpon* Ait.) were analyzed for factors relating to fruit quality and processability to develop selection procedures for breeding programs. High correlations were obtained between tristimulus reflectance measurements on whole or pureed cranberries and the juice color, determined by spectrophotometric or tristimulus transmission measurements. Differences between cranberry samples in the proportions of individual anthocyanins were small and not correlated with berry or juice color. A 3-stage sequence of simple measurements, entailing minimal sample preparation, was developed for selection. First- and second-stage selections were based on the application of discriminant analysis to tristimulus reflectance data obtained with whole and pureed cranberry samples, respectively. In the third stage, selections were based on analytical measurements performed on juice prepared from samples selected in the preceeding stages.**

In trying to develop superior cultivars, breeders typically generate thousands of seedlings, each requiring evaluation so that selections can be made. Among the criteria used for selection, fruit quality and processability rank high in importance but are difficult to apply under field conditions. With cranberries, the juice yield, color, sugar content, and acidity have been identified as important quality attributes for the processing industry (M. S. Starr, personal communication).

Methods for the determination of total and individual anthocyanins in cranberry products (1, 2, 4–6) and for the evaluation of color in cranberry juice (7) are well established. However, attempts to relate the surface color or total anthocyanin content of cranberry fruit to juice color have met with limited success (3; M. S. Starr, personal communication). Schmid (10) investigated cultivar, seasonal, and ripening effects on fruit size, anthocyanin content, titratable acidity, sugars, pectins, and other constituents with 12 cranberry cultivars. However, the large-scale screening of seedlings for genetically linked differences in color or other fruit quality attributes has not been reported.

We describe a sampling protocol for the sequential examination of whole and pureed cranberry fruits and the expressed juice, measuring parameters relating to the quality and composition of fresh and processed cranberries. We applied these methods to several different cultivars with the goal of developing selection procedures suitable for cranberry breeding programs.

Materials and Methods

Nondestructive evaluation of cranberry samples. We obtained samples of berries from 45 cranberry clones (1980 crop) grown at the Univ. of Massachusetts Cranberry Experiment Station in E. Wareham, Mass.; one set of samples was received in December and another in February. We also obtained a small number of samples (1981 crop) from the USDA Blueberry and Cranberry Research Center in Chatsworth, N.J. The cranberries in each sample were sorted visually into 2 subsamples—a) berries showing maximum color development for that sample (dark) and b) all other berries (light).

Nondestructive reflectance measurements were made on each set of subsamples with a Gardner XL-23 Tristimulus Colorimeter. A 40 × 57.1 (I.D.) mm cylindrical optical cell was filled to the top with intact berries, weighing about 35–40 g, and values of the tristimulus coordinates L, a_L, and b_L were measured. The subsamples then were bottled in pint jars and stored at −18°C until required for further analysis.

Reflectance of pureed fruit. About 75-g portions of each cranberry subsample were thawed overnight in a refrigerator and then homogenized for 2 min at high speed in a semimicro stainless-steel blending container (250 ml capacity) on a Waring base. The tristimulus coordinates were measured as before but with about 45-g portions of homogenate (brought to room temperature) in the optical cells.

Alcohol extraction: determination of total anthocyanins and flavonols. We used a modification of Deubert's rapid method (2) to determine total anthocyanins and flavonols in cranberry samples. Equal weights of cranberry homogenate and extracting solvent [95% ethanol:1.5 M HCl (85:15)] were combined in a Waring Blendor and blended for 2 min at high speed. A 10-g aliquot (equivalent to 5 g of cranberries) and a 0.5-g portion of Celite Analytical Filter Aid were combined and transferred with 15 ml of extracting solvent to a Whatman No. 5 filter disc in a 100-mm diameter Buchner Funnel under suction. Cranberry pigments were extracted with 3 successive 20-ml portions of solvent. The volume of the filtered extract, usually about 80 ml, was determined, and dilutions were made with additional extractant to adjust the anthocyanin concentration to a suitable range for spectrophotometric analysis. Absorbance measurements were made at 535 and 374 nm with with a Perkin-Elmer Model 552 UV-Visible Spectrophotometer, and values of the total anthocyanin and flavonol contents (mg %) were calculated from extinction coefficients given by Fuleki and Francis (4) and by Lees and Francis (8), respectively.

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Juice preparation and analysis. For juice preparation, frozen cranberries were thawed overnight in a refrigerator, brought to room temperature, and then chopped (3–4 slices per berry). A 50-g portion of chopped berries (including juice liberated during thawing and chopping) and 1.7 g of rice hulls, a commercial press aid, were weighed into the cylinder [5.72-cm (2-1/4-inch) diameter] of a Succulometer Cell (Model CR-1, Food Technology Corp., Rockville, Md.), and covered with a 5.72-cm (2-1/4-inch) diameter felt filter pad (Fred S. Carver, Inc., Menomonee Falls, Wisc.). The juice was expressed by applying a 1814.4-kg (4000-lb.) force to the Succulometer Cell with a Carver Model C 12 Ton Laboratory Press, equivalent to a pressure of 70.3 kg/cm^2 (1000 psi), for 10 min, then releasing the pressure, redistributing the contents of the cell, and reapplying the same pressure for an additional 10 min. The volume of the expressed juice, usually about 40 ml per 50 g berries, was measured. Lower yields resulted when the rice hulls were omitted. The cranberry juice was analyzed for soluble solids with a Bausch & Lomb Abbe-3L Refractometer and for pH. The titratable acidity, expressed as milliequivalents of acid per 100 ml of juice, was determined by diluting 5 ml juice with 45 ml distilled H_2O and titrating to a pH 8.1 endpoint with 0.1 N NaOH.

Tristimulus transmission and spectrophotometric measurements. Cranberry juice samples were diluted 1:5 with distilled H_2O and clarified by the addition of 5% Celite Analytical Filter Aid, followed by filtration through a Whatman No. 5 filter under suction. A further 1:4 dilution of the filtrates (1:20 overall), adjusted to a pH between 2.6 and 2.8 (the pH of fresh cranberry) with concd HCl, was used as a basis for comparing the color of juice from each cranberry subsample. Values of the visible λmax and the absorbance at that wavelength (Aλmax) were measured with the spectrophotometer. A 50-ml aliquot was placed in the optical cell of the tristimulus colorimeter; values of L, a_L, and b_L were obtained in the light transmission mode. In addition, values of the hue angle $\theta = \tan^{-1} b_L/a_L$ and a*, an expanded scale color parameter (7), were computed from the tristimulus data. Tristimulus transmission measurements also were made on a second dilution of the clarified juice, adjusted in anthocyanin concentration on the basis of the absorbance of the 1:20 dilution such that Aλmax was 1.0. Total anthocyanin in cranberry juice samples was determined by a modification of the method of Fuleki and Francis (5) wherein the diluted juice was adjusted to pH 1.0 with concd HCl, Aλmax was measured, the pH was readjusted to 4.5 with 10% NaOH, and the spectrophotometric measurement was repeated.

HPLC determination of individual anthocyanins. The individual anthocyanins in cranberry juice were determined in duplicate by high performance liquid chromatography (HPLC) with a Waters chromatographic system (Waters Associates, Inc., Milford, Mass.). Prior to analysis, clarified 1:5 dilutions of juice were passed through an 0.2-μm membrane filter (Gelman Sciences, Inc., Ann Arbor, Mich.). Aliquots of filtrate (25μl) were injected onto a Waters 4 mm × 30 cm μBondapak C_{18} column, at a flow rate of 1.0 ml/min using as the mobile phase a solvent mixture comprising water–acetonitrile–acetic acid–phosphoric acid (81.7:8.4:8.4:1.5), a mixture similar to that used by Strack et al. (11) for anthocyanins. The column effluent was monitored for anthocyanins with a Waters Model 440 Absorbance Detector at 546 nm. Peak areas were quantitated with an electronic integrator (Hewlett-Packard Model 3370A, Avondale, Pa.), and the proportions of the individual anthocyanins in each sample were calculated from the peak areas, assuming the extinction coefficients to be approximately equal (4, 5).

Statistical methods. A 2-stage discriminant analysis (9) was applied to the tristimulus reflectance (L, a_L, and b_L) data for whole (first-stage) and pureed (second-stage) cranberries and corresponding determinations of total and juice anthocyanin content to distinguish between "good" and "poor" cranberries where "good" and "poor" are defined in terms of the berry or juice anthocyanin contents. This definition represents a strategy, jointly agreed to by breeder and client (i.e., USDA, grower cooperative, processing industry), that is based on previous studies of cultivar differences in anthocyanin content and variability due to climatic factors, location, and ripeness. The technique of discriminant analysis develops a rule which states that if a linear combination of the observed predictor variables (tristimulus coordinates) is greater than or less than a given value, then the sample on which those observations are made is classified into either one group or the other. The specific linear combination and the given value are computed from a "learning set" of samples from each population by a least-squares technique. In our study, the cranberries received from Massachusetts in December were used as the learning set. The rules developed with this set were tested with the samples obtained in February. The data for the 2 sets of samples were then combined, and new rules based on the pooled data were derived. These rules were then tested with the cranberry samples obtained from the New Jersey laboratory in 1981.

Results and Discussion

Variation in composition and quality factors. In this study, we examined dark and light subsamples of diverse cranberry cultivars with the expectation that our analytical measurements would produce a wide range of values (Table 1) and that useful correlations between such measurements would be found. Reflectance data obtained by the analysis of whole and pureed cranberries showed large differences among cultivars and between dark and light subsamples. The L value for pureed berries, an indication of sample lightness, showed the widest range among the reflectance parameters measured. These data were obtained with samples weighing 35–40 g for whole cranberries and 45 g for pureed berries. We found that the sample weights could be as low as 25–30 g for whole berries and 20 g for purees without significantly affecting the reflectance data. The ability to use a small sample size would be advantageous with seedlings bearing few berries, although such samples might not be representative due to variation in berry size and/or ripeness.

Tristimulus measurements performed in the transmission mode with diluted cranberry juice describe different attributes of juice color, probably the most important quality factor to be evaluated. When 1:20 dilutions of filtered juice pressed from cranberry subsamples were compared, all tristimulus parameters, except the hue angle θ, showed wide variation, indicating differences in color intensity but not hue. Differences in hue were even smaller when samples were diluted to a constant anthocyanin content corresponding to Aλmax = 1.0.

Differences between subsamples in the total anthocyanin and flavonol contents of whole berries and in the juice anthocyanin content were large, as compared to the errors associated with these measurements. Analyses of several cultivars with 6 replications yielded standard errors of 3.9 mg anthocyanin and 3.0 mg flavonol per 100 g of whole berries and 3.5 mg of anthocyanin per 100 ml of juice. Individual anthocyanins, designated on our HPLC chromatograms (Fig. 1) as peaks 1, 3, 4, and 6 (2 and 5 being minor components), were identified tentatively as cyanidin-3-galactoside, cyanidin-3-arabinoside, peonidin-3-

Table 1. Variation in tristimulus parameters and composition for berries and juice from dark- and light-colored subsamples of 45 cranberry clones.

Parameter[z]	Dark berries			Light berries		
	Mean	SD	Range	Mean	SD	Range
Whole berry reflectance						
L	17.3	1.1	14.3– 20.0	20.7	1.8	17.6– 23.5
a_L	13.9	3.2	7.4– 22.6	22.3	3.8	16.2– 29.6
b_L	−0.4	1.2	−3.0– 2.2	1.9	3.3	−5.6– 5.9
Pureed berry reflectance						
L	10.9	1.8	3.4– 13.7	14.8	1.6	12.5– 17.4
a_L	27.0	2.8	19.0– 32.8	32.4	2.6	28.7– 37.8
b_L	4.0	0.9	1.5– 5.7	6.5	1.0	5.1– 8.2
Juice (1:20) transmission						
L	56.5	4.5	43.1– 67.0	65.1	3.4	58.5– 71.2
a_L	66.3	4.0	54.7– 74.7	54.9	6.3	35.2– 64.8
b_L	30.6	2.2	23.2– 33.8	24.2	3.6	18.1– 31.2
θ	24.8	0.8	21.9– 26.2	23.4	1.4	20.7– 25.8
a*	214.9	3.9	208.0–227.2	208.8	1.7	206.2–213.0
Juice (A = 1) transmission[y]						
θ	24.8	0.6	23.6– 26.3	24.7	0.6	23.3– 25.7
Whole berry composition						
Total anthocyanin (mg/100 g)	86.3	27.5	45.9–171.9	41.2	12.3	24.1– 63.3
Total flavonol (mg/100 g)	44.6	10.9	25.4– 90.4	26.5	3.8	17.9– 32.0
Juice composition						
Yield (ml/100 g)	80	1.7	77 – 84	80	1.2	76 – 90
pH	2.6	0.05	2.5– 2.7	2.6	0.05	2.5– 2.7
Titratable acidity (meq/100 ml)	36.4	2.7	31.6– 45.5	40.6	3.1	35.9– 48.4
Soluble solids (%)	9.2	0.6	7.2– 10.4	9.3	0.4	8.4– 10.1
Total anthocyanin (mg/100 ml)	51.1	18.9	24.2–123.0	26.4	6.3	16.4– 43.4
Distribution of individual anthocyanins (%)						
HPLC Peak 1	25.8	3.2	18.5– 31.0	24.4	3.1	19.1– 29.6
3	15.6	1.9	11.8– 19.3	16.9	2.3	12.7– 21.4
4	40.1	3.2	34.1– 46.9	39.0	3.4	32.6– 46.0
5	3.1	0.5	2.1– 4.4	2.6	0.6	1.8– 3.9
6	15.2	2.0	11.8– 20.3	17.1	2.1	13.5– 20.8

[z]As defined in text.
[y]Juice diluted so that Aλmax = 1.0.

galactoside, and peonidin-3-arabinoside, respectively, based on the retention times of standards, their order of elution, and their relative proportions (1, 6). The proportions of individual anthocyanins in the juice of different cranberry cultivars varied within narrow limits and were similar for dark- and light-colored subsamples of the same cultivar. No relationship was seen between the total anthocyanin content or the hue angle and the anthocyanin distribution in the juice of different cultivars. No differences were seen in the anthocyanin distribution in samples of 'Franklin', 'Early Black', and 'Pilgrim' cranberries obtained from Massachusetts in 1980 and from New Jersey in 1981, even though total anthocyanin in the juice of these samples varied substantially.

Likewise, differences among cultivars and between dark- and light-colored subsamples in the yield, pH, titratable acidity, and soluble solids content of cranberry juice were small.

Correlation between properties of berries and juice. Correlations between nondestructive reflectance measurements, performed on whole cranberries, and the pigment content or colorant properties of the berries and corresponding juice (diluted 1:20) were significant but not high enough to suggest a simple screening test to select superior seedlings (Table 2). However, by the application of discriminant analysis to these reflectance data, we were able to establish rules constituting a first stage of selection, permitting us to identify cranberry samples having total or juice anthocyanin contents above specified values (e.g., 100 mg/100 g or 60 mg/100 ml, respectively). These rules, described by the inequalities shown in Table 3, were derived from the entire 1980 data set after we had first demonstrated the accuracy of similar rules, derived from the smaller learning set (cranberry samples received in December). We obtained more accurate results when the rules were based on berry rather than juice anthocyanin content. For example, using a berry anthocyanin content of 100 mg per 100 g as a target (rule 1b), we would have accepted 11 of the 12 "high" anthocyanin cranberry samples and rejected 39 of the 53 "low" anthocyanin samples in the 1980 data set.

The use of a second stage of selection, with rules based on reflectance data obtained with pureed cranberries, greatly improved the accuracy of the selection process. This result followed from the higher correlations obtained between these reflectance data and the berry or juice anthocyanin content. If we again used 100 mg anthocyanin per 100 g as a target (rule 2b) in the second stage of selection, only samples accepted in the first stage (25 out of 65 with the 1980 data set) would be pureed and analyzed. Using rule 2b, we would have accepted all 11 of the

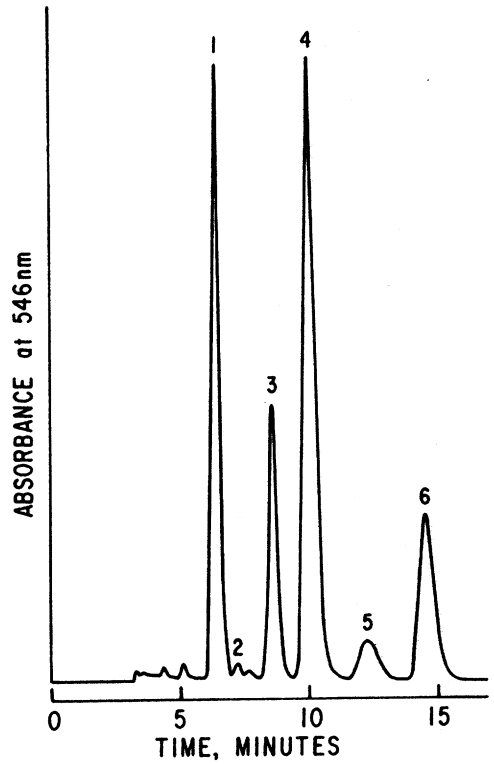

Fig. 1. HPLC of anthocyanins from 'Franklin' cranberry juice. Peaks 1, 3, 4, and 6 are tentatively identified as cyanidin-3-galactoside, cyanidin-3-arabinoside, peonidin-3-galactoside, and peonidin-3-arabinoside, respectively.

"high" anthocyanin samples previously accepted in the first stage, and we would have rejected 12 of 14 "low" anthocyanin samples incorrectly classified in the first stage. By the standards for selection given in Table 3, only one of the 11 cranberry samples harvested in 1981, a borderline case (total anthocyanin in the berry and juice being 88.5 mg/100 g and 58.9 mg/100 ml, respectively), should have been selected. Application of the selection rules to tristimulus data obtained with these samples did in fact result in the rejection of the "low" anthocyanin samples, with the exception of the borderline case (rules 2a, 2b, and 2c) and a second "low" anthocyanin sample (rules 2b and 2c). In contrast to the results obtained the previous year, better results were obtained with the 1981 samples when the rules for selection were based on the juice anthocyanin content rather than on the berry anthocyanin content; the choice of the most efficient rule may be a function of sample growing location, seasonal differences, or berry ripeness.

A third stage of the selection process, applied only to samples selected in the second stage, entailed the expression of cranberry juice and the measurement of juice yield, pH, titratable acidity, and soluble solids; these quality factors did not correlate with any of the tristimulus or spectrophotometric measurements performed in our study. In addition, a standard dilution of cranberry juice was analyzed spectrophotometrically and with the tristimulus colorimeter operated in the transmission mode to confirm that the sample met the desired specifications for anthocyanin content and color. Analytical data for the 11 "high" anthocyanin and the 2 "low" anthocyanin samples selected from the 1980 data set by rules 1b and 2b are given in Table 4.

Distinctions between these 2 groups of samples in total juice anthocyanin content were not sharp; in fact, selection W-72,

Table 2. Correlation between tristimulus reflectance measurements for whole and pureed cranberries and the pigment content and color of the fruit.

	Correlation coefficient					
	Total anthocyanin		Total flavonol	Juice (1:20)		
Parameter	Fruit	Juice	in fruit	L	θ	a*
			All berries			
Whole berry						
L	−0.68**[z]	−0.61**	−0.56**	0.73**	−0.49**	−0.67**
a_L	−0.73**	−0.71**	−0.53**	0.78**	−0.48**	−0.75**
b_L	−0.49**	−0.49**	−0.35**	0.57**	−0.48**	−0.53**
Puree						
L	−0.82**	−0.74**	−0.63**	0.81**	−0.43**	−0.78**
a_L	−0.83**	−0.81**	−0.57**	0.84**	−0.27*	−0.84**
b_L	−0.88**	−0.82**	−0.67**	0.89**	−0.37**	−0.78**
			Dark berries			
Whole berry						
L	−0.47**	−0.42**	−0.18	0.43**	0.13	−0.45**
a_L	−0.54**	−0.60**	−0.15	0.57**	0.14	−0.60**
b_L	−0.37**	−0.45**	−0.11	0.44**	0.04	−0.46**
Puree						
L	−0.67**	−0.59**	−0.35**	0.60**	0.00	−0.60**
a_L	−0.71**	−0.75**	−0.27**	0.74**	0.30	−0.78**
b_L	−0.80**	−0.78**	−0.41	0.80**	0.26	−0.83**
			Light berries			
Whole berry						
L	−0.58*	−0.50	−0.58*	0.55	−0.46	−0.57*
a_L	−0.73**	−0.59*	−0.57*	0.60*	−0.57*	−0.62*
b_L	−0.48*	−0.49	−0.22	0.50	−0.50	−0.50
Puree						
L	−0.92**	−0.80**	−0.73**	0.82**	−0.78**	−0.83**
a_L	−0.85**	−0.70**	−0.54*	0.76**	−0.74**	−0.76**
b_L	−0.90**	−0.77**	−0.68**	0.81**	−0.78**	−0.81**

[z]Significant at 5% (*) or 1% (**) level.

one of the 2 "low" anthocyanin samples (classified on the basis of berry anthocyanin content) contained as much anthocyanin in the juice as did 2 of the "high" anthocyanin samples, selections MC and 6. Inconsistencies between the berry and juice anthocyanin contents probably are indicative of the inefficiency of pigment extraction from epidermal cells by the liberated cranberry juice during pressing (3).

In the third stage, cranberry seedlings might be selected on the basis of their superiority in total anthocyanin content in the berry and/or juice. The soluble solids, titratable acidity, or sugar–acid ratio also might be considered in making third-stage selections. Our values of the juice pH, titratable acidity, and soluble solids content were similar to those reported by Schmid (10) for the same cultivars. Our samples, which had been presorted on the basis of berry color, all contained more total anthocyanin (berry) than was found by Schmid. 'Franklin', selection CK, and 'Early Black' rank high among the samples compared in this study. The distribution of individual anthocyanins in a cranberry juice sample need not be considered in third-stage selection, since correlations between the individual anthocyanins and the colorant properties of berries and juice were not significant. We noted earlier the lack of variation in hue angle in solutions adjusted to a constant anthocyanin concentration. This is probably a consequence of the relative uniformity of cranberry cultivars with respect to anthocyanin distribution, and the similarity of cranberry anthocyanins with respect to their visible absorption maxima and extinction coefficients (5).

Table 3. Application of discriminant analysis to selection of cranberry clones on basis of tristimulus reflectance data.

Stage of selection	Standard for selection[z]	Rule no.	Rule: select if	1980 Cranberry samples						1981 Cranberry samples	
				High anthocyanin subsamples[y]			Low anthocyanin subsamples[y]			Low anthocyanin subsamples[y]	
				A	R	A(%)	A	R	R(%)	A	R
First (whole berry reflectance)	Berry Tacy>90	1a	$2.45L + 2.23a_L - 1.53b_L < 76.73$	15	5	75	14	31	69	4	7
	Berry Tacy>100	1b	$4.21L - 5.19a_L + 2.23b_L > -3.32$	11	1	92	14	39	74	7	4
	Berry Tacy>110	1c	$3.89L - 5.94a_L + 3.28b_L > -13.27$	7	1	88	11	46	81	5	6
	Juice Tacy> 50	1d	$2.95L - 1.85a_L + 0.74b_L > -18.13$	16	4	80	13	32	71	0	11
	Juice Tacy> 60	1e	$3.07L - 3.59a_L + 0.35b_L > -2.96$	9	2	82	17	37	68	0	11
	Juice Tacy> 70	1f	$3.31L + 2.40a_L - 1.99b_L < 89.19$	4	1	80	17	43	72	1	10
Second (pureed berry reflectance)	Berry Tacy>90	2a	$1.02L + 1.68a_L - 10.84b_L > 14.75$	14	1	93	1	13	93	1	3
	Berry Tacy>100	2b	$1.08L + 2.07a_L - 11.63b_L > 22.94$	11	0	100	2	12	86	2	5
	Berry Tacy>110	2c	$4.67L + 4.08a_L - 21.74b_L > 77.49$	7	0	100	1	10	91	2	3
	Juice Tacy>50	2d	$1.01L - 1.81a_L + 6.30b_L < -13.05$	14	2	88	3	10	77	0	0
	Juice Tacy>60	2e	$1.12L - 0.03a_L + 0.23b_L < 11.50$	7	2	78	4	13	76	0	0
	Juice Tacy>70	2f	$5.49L + 7.05a_L - 50.82b_L > 70.46$	3	1	75	4	13	76	0	1

[z]Tacy = total anthocyanin content, mg/100 g or mg/100 ml for whole berry and juice, respectively.
[y]Based on spectrophotometric analysis of berry or juice. A = accepted; R = rejected.

Table 4. Characteristics of cranberry samples selected by discriminant analysis of tristimulus reflectance data[z].

Sample[y]	Juice yield (ml/100 g)	pH	Titratable acidity (meq/100 ml)	Soluble solids (%)	Total anthocyanin	
					Berry (mg/100 g)	Juice (mg/100 ml)
"High" anthocyanin						
'Franklin' (2)[x]	80	2.68	33.2	7.2	172	123.0
MC	78	2.57	38.3	9.6	152	54.6
'Franklin'	80	2.57	37.3	7.8	148	84.0
6	80	2.64	34.3	9.4	139	54.4
CK (2)[x]	80	2.62	36.2	9.1	138	107.4
CK	82	2.55	37.6	9.5	116	75.9
'Early Black'	82	2.60	40.6	7.5	116	69.3
'Black Veil'	82	2.61	32.2	9.1	115	58.4
ME-25	78	2.68	41.6	9.1	110	61.1
'Bergman' (2)[x]	80	2.66	32.4	9.6	104	61.6
'Holliston'	80	2.60	37.8	9.4	102	68.6
"Low" anthocyanin						
W-72	82	2.62	34.6	8.8	92.8	54.7
'Beckwith'	80	2.65	32.6	9.2	87.1	45.7

[z]Target of selection was berry total anthocyanin > 100 mg/100 g (rules 1b and 2b); i.e., "high" anthocyanin > 100 and "low" anthocyanin < 100.
[y]Dark subsamples only. Includes cultivars and unnamed selections.
[x]'Franklin' (2), CK (2), and 'Bergman' (2) samples from second Massachusetts set.

Conclusions

A 3-stage sequence of relatively simple tristimulus and spectral measurements, entailing minimal sample preparation, can be used to identify cranberry samples having superior quality attributes. This procedure may be useful as a selection tool for cranberry breeding programs.

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